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Analysis of the variable behavior manifested in all Navy/Marine major aircraft accident rates

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ANALYSIS OF THE VARIABLE BEHAVIOR MANIFESTED IN ALL NAVY/MARINE MAJOR AIRCRAFT ACCIDENT RATES

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

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ACCIDENT RATES

by

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and

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the accident, the number of night carrier landings in the previous 30 days, and the number of daylight carrier landings in the previous 30 days explained 46.65% of noted accident rate variance. The results corroborate previously held theories that pilot error is the single largest causal factor in aircraft accidents.

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I. INTRODUCTION

Dollar costs and the number of aviation personnel killed each year have often been used to emphasize the importance for determining a viable method to reduce Navy and Marine aircraft accidents. Research efforts conducted to date have dealt primarily with attempts to identify and understand the factors which were instrumental in causing accidents. Once identified, these pertinent factors or variables were to become the crux for developing predictive models for accident occurrence.

Aircraft accidents have been broadly categorized in terms of causal factors which were determined from extensive post-accident analysis by accident investigation teams. Aircraft or ground support equipment failures, weather, pilot or other flight personnel error, maintenance induced equipment malfunctions, and shortcomings in design have all been listed as primary cause for occurrence of major aircraft accidents. An accident is designated as a major accident if: 1) loss of life is involved; 2) complete loss of an aircraft is involved; or 3) substantial damage occurs to any aircraft involved where substantial damage is defined in Appendix A of OPNAVINST 3750.6 (Series). Of these, the most common cause sited has been pilot error. Brictson, et al. (1969), studied aircraft carrier landing accidents spanning the years 1965 through 1969. Although the study was limited to attack and fighter aircraft, the proportion of accidents attributed to

pilot error is indicative of the inordinately high aircraft and personnel loss rates incurred over all aircraft types. Approximately seventy-eight percent of accidents studied were linked to pilot error as being the primary causal factor. Over eight percent of the accidents were attributed to errors committed by other supporting personnel, leaving only thirteen percent to be distributed among weather, aircraft failure, equipment failure, and other causes. Brictson noted that the preponderance of accidents were of two types, hard landings and undershooting the landing area. Hard landings were more prevalent during daylight hours and undershots during hours of darkness. As expected, small carriers accounted for approximately seventy percent of the total accidents even though flight activity was less than on large carriers.

Studies conducted for the Royal Air Force by Goorney (1965) were an attempt to subcategorize pilot error into its component parts, more molecular in scope than had previously been done. He concluded that lack of current flying experience, fatigue, complacency, personal worries, and emotional stress directly contributed to pilot error and, if monitored, could be used to predict the likelihood of pilot error related accidents. He attributed fatigue to pilots having had excessive ground duties prior to flying and aircrew complacency to lengthy flights in relatively simple aircraft. Questionnaires distributed among the ninety accident involved pilots making up his sample indicated that emotional stress

and personal worries were caused by marital, dating, housing, financial, and work oriented problems.

Current flying experience or pilot proficiency has been singled out by some analysts as the best predictive measures of pilot error accidents. Keller (1961) hypothesized that the amount of flight time logged by a pilot during a given period was positively correlated with optimal proficiency. He intimated that were a pilot to fly the proper amount, he would attain a safe, proficient ability as a pilot. Unfortunately, the hypothesis was not backed with specific guidelines of how to ascertain the necessary hours of flight time which would neither favor fatigue nor insufficiency over optimal proficiency.

Collicot, et al. (1972) categorized accident causal factors into pilot error, material failure, maintenance error, and miscellaneous other causes. In comparing Navy-Marine F-4 accident rates with Air Force accident rates, the authors attributed maintenance error disparities to the fact that Air Force F-4 aircraft realized approximately one-tenth of the Navy-Marine cannibalization rate to meet sufficient operational aircraft requirements. Naval-Marine officer job rotational policies were singled out as adversely affecting pilot proficiency. The policies result in lower in-type flight hours for Naval-Marine aviators than their Air Force counterparts enjoy. The authors also compare accident rates of single-seat aircraft with those of dual piloted aircraft. They note that when operations required of the aircraft are

equalized as best possible, the dual piloted aircraft have noticeably fewer accidents per ten thousand flight hours than do the single-seated versions. Operational F-4 aircraft were used to make the comparisons, comparisons limited to instrument, take-off, and landing phases of flight. Throughout the analysis, the authors continually refer to the importance of pilot proficiency but now, unlike prior authors, have alluded to the possibility of pilot mental overload being critical in the determination of a prime factor in pilot error.

A shift occurred in the emphasis from pilot error induced accidents being caused by lack of pilot proficiency to implications that the pilot is all too often proficient but may be in a state of temporary mental overload. Data extracted from National Transportation Safety Board records led Kowalsky, et al. (1974) to posit causal factors for the high pilot error rate. Pilot error had heretofore inferred that practice of pilot procedure was the only method of improving pilot proficiency and thus reducing error. Kowalsky and his co-researchers applied cluster analysis and pattern recognition techniques to their air carrier accident data and found that for non-training, non-midair accidents, the single most important human causal factor was that pilots were often temporarily overloaded and incorrectly evaluated information inputted to them during the overload period. Training flight accidents were attributed to instructor pilots delaying

recovery or corrective actions until conditions became too far out of tolerance to properly affect recovery. Midair collisions were best explained by pilots attempting to meet time schedules or destinations where such outcomes were improbable at best.

Burin (1974) took a slightly different tack in treating the problem of aircraft accidents. Rather than dwell on accident investigator assigned causal factors, he constructed a measure of risk for the twelve individual aircraft models which contributed the highest towards total flight hours and accident occurrence in the Navy-Marine inventory. Four areas of risk were defined to include take-off, in-flight, transition, and landing evolutions. Accidents were assumed to occur in accordance with a Poisson process. Using data which covered Fiscal Years 1969 through 1973 obtained from the Naval Safety Center, he constructed a risk index for each aircraft considered. The risk index consisted of the data derived risk in each of the four phases of flight multiplied by the associated percentage of an average flight spent in each phase. Although the model does in fact conform to the actual individual accident rates observed, it does little to isolate one or more specific factors enabling corrective action to be taken to reduce the very accident rate it models.

A great deal of effort has been expended since the advent of the Naval Safety Center in maintaining extensive data banks of accident related information. Statistical analysis

of available data, much of which can be construed as measures of pilot proficiency, should enable predictive mathematical models to be constructed. Such an undertaking was attempted by Myers (1974). He hypothesized that measures of pilot experience and proficiency, then available in collection agency data banks, would suffice to form an adequate foundation for accident rate analysis. He selected ten variables or factors from the Individual Flight Activity Reporting System (IFARS) data bank to which he later applied statistical techniques of principle component analysis and cluster analysis. The analysis was limited to two groups of fifty pilots each. One group was composed of pilots having been involved in aircraft accidents, the other of pilots free of any accident participation. Results were not as pronounced as was desired, however. Small sample size is suspect in having surpressed accident predictive results.

The authors of this writing agree with the basic premise promoted by Myers and others. Sufficient data should be currently available, from which predictive capability is extractable. The variable nature of the monthly accident rate suggests underlying factors causal and thus definable in their role of accident perpetration. What common factors act to cause accident rate fluctuations? If statistical analysis can isolate variable measures associated with pilot proficiency, aircraft maintenance, flight mission categories, or fiscal management which vary directly or inversely with

accident rate, then predictive and thus preventative knowledge can assist in suppressing dollar and human life costs resulting from aircraft accidents.

II. NATURE OF THE PROBLEM

Past monthly major accident rates have been computed for all Navy/Marine aircraft by the Naval Safety Center (NSC), Norfolk, Virginia. The rate is defined as the total number of accidents in a given month multiplied by a constant factor of ten thousand and then divided by the total monthly hours flown. Major accidents, by definition, are characterized by extensive aircraft damage, measured in necessary man-hours to effect repair if repair is possible, or loss of life.

Monthly accident rates exhibit a marked variability when each calendar month is compared to other months. Some monthly rates, however, seem to be consistently high. January and July rates are higher than the yearly average for four of the six sequential fiscal years beginning with 1968. This phenomena has also been noted in U.S. Air Force accident rates as noted by Zeller and Marsh (1973). Such seasonal trends and monthly rate variability cannot be attributed solely to weather. The purpose of this paper is to explore accident rate dependence on time related variable measures in hopes that one or more of these measures can be identified for later use in accident rate reduction.

III. ANALYTICAL PROCEDURES

A. DATA SOURCE

OPNAVINST 3750.6 (Series) delineates the requirements and procedures for reporting each aircraft incident or accident involving Naval and Marine aircraft. The type and number of different reports required for each accident varies, the extreme case to include seven separate reports with accompanying photographs of the crash site, terrain and flight path sketches, and detailed statements from knowledgeable witnesses or experts. The reports are to be forwarded to NSC for inclusion into their master data bank. Accident data currently available from NSC spans the period from the early 1960's to the present. Approximately eighty separate variable measures are available for each accident occurrence.

B. DATA SELECTION

The initial step in the conduct of the current accident rate analysis was to select appropriate data points or variable measures. A data point for an accident was considered to be any suitable variable measure associated with the accident. Suitable data points could have taken the form of accident occurrence date, pilot age, or aircraft model. A particular data set consisted of data points for a specific accident.

A sufficient number of data sets had to be incorporated into the analysis to facilitate viable statistical results.

However, the span of time defined by the data sets to be analyzed had to be chosen with care. Were a time span chosen during which numerous types of aircraft were removed from the operational inventories, undesirable effects could have resulted. Due to the rapid advances which had occurred in aircraft technology, data from accidents prior to Fiscal Year 1969 was not deemed suitable for analysis inclusion with the present inventory of aircraft. In the opinion of the authors, data for accidents which occurred after Fiscal Year 1974 was suspected of containing gaps in information due to continuing investigations by aircraft custodians. The final decision was, therefore, to include all major accidents which occurred during the Fiscal Years 1969 to 1974, inclusive. Two-thousand-one-hundred-ten accidents or data sets available within the six-year period selected were all considered suitable for analysis.

The NSC data bank provided a ready source of numerous data points for each accident or data set. Selection of appropriate data points required that each point be time dependent. Subjective decisions of time dependency were carefully made for each data point considered for analysis. Data point time dependency and subsequent selection was based on the variable descriptions contained in the Manual of Code Classification for Navy Aircraft Accident, Incident and Ground Accident Reporting (Code Manual) promulgated by NSC. The number of different data points selected were not governed

solely by the current study but also by the requirement for follow-on studies to be conducted by this institution. Continuity of successive studies must necessarily be driven by the consistency of logic used in formulation of a data selection criterion.

Fiscal funding policies at the squadron level was held suspect in contributing towards the above average observed accident rates for January and July. Financial data of this sort, however, was not available from the NSC data bank. An extensive search for suitable data proved to be unsuccessful and time constraints precluded further endeavors into this field.

A historical breakdown of individual squadron flight hours per month and flight hours by type aircraft were not available from NSC. The information was deemed necessary for in-depth analysis because of its necessity in calculating accident rates by aircraft type. Because of the varied flight envelopes in which different aircraft operate, some types were assumed to contribute more heavily towards the overall accident rate variability than were others. To properly explain the variability, then, required an analysis at the aircraft type level. NSC found a source of the needed aircraft type and squadron flight data in digital tape form from the Naval Supply Corps maintained Maintenance Data Collection System (MDCS) records kept at Mechanicsburg, Pennsylvania.

A total of thirty different data points for each of the two-thousand-one-hundred-ten aircraft accidents were requested from NSC. Table 1 lists the variable measures obtained from NSC computer data banks. All data was received from NSC on eighty column Hollerith cards and was encoded in accordance with the Code Manual description.

Ten data points from each data set of thirty possible points were selected for inclusion into the current analysis. These variables represent broad causal categories, some of which were involved in earlier studies mentioned in the introduction. Table 2 lists the variables selected for the current study. Pilot age and total flight time in the aircraft model involved in the reported accident have been considered to be measures of pilot experience. Such measures of experience should exhibit negative correlation with accident rate if they are in fact true measures of experience. Age has been considered to be a primary measure of caution by philosopher and insurance corporations alike when the subject of risk has been broached. The Navy has and still is measuring pilot experience in terms of "seat time" logged in applicable aircraft models.

Pilot proficiency, a measure of recent hours flown, has also been directly tied to the maintenance or increase of flight prowess for Naval Aviators. This factor also complies with the age old adage of "practice makes perfect" and should be negatively correlated to accident rate. Measures of pilot

TABLE 1

DATA SET REQUESTED FROM NAVAL SAFETY CENTER

Data concerning the pilot:

1. Age
2. Injuries
3. Number of previous service tours
4. Total flying time in aircraft model in which accident occurred
5. Total flight hours in previous ninety days
6. Total nighttime flight hours in previous ninety days
7. Total daylight carrier landings in previous thirty days
8. Total night carrier landings in previous thirty days
9. Number of years as designated Naval Aviator

Data concerning aircraft:

1. Model
2. Damage
3. Number of tours between major aircraft rework
4. Type of last major inspection
5. Hours since last inspection
6. Identification of the system or component failure

Data concerning the flight:

1. Major command
2. Reporting custodian
3. Ship's hull number (if applicable)
4. Marine Air Wing (if applicable)
5. Location
6. Flight Purpose Code
7. Type of operation code
8. Phase of operation in which the accident occurred

Data concerning the accident:

1. Accident identification number including calendar date
2. Other aircraft damaged
3. Other personnel injured
4. Contributing causal factors
5. Special data not otherwise listed
6. Weather
7. Accident rate for the month in which the accident occurred

TABLE 2

DATA SET INCLUDED IN CURRENT STUDY

1. Accident rate by month (RATE)
2. Pilot's age (AGE)
3. Total flight time in accident involved aircraft model (TTIME)
4. Total flight time during ninety days preceding accident (TOT90)
5. Total night flight time during preceding ninety days (NITE90)
6. Daylight carrier landings during preceding thirty days (CLDAY)
7. Night carrier landings during preceding thirty days (CLNITE)
8. Number of aircraft tours (ACTOUR)
9. Aircraft flight hours since last major or minor inspection (ACHRS)
10. Flight Purpose Code

proficiency selected for inclusion were total flight time in the last ninety days and nights, total flight time in the last ninety nights, the number of carrier landings in the last thirty days, and the number of carrier landings in the last thirty nights. Although flight hour data points were available for twenty-four and forty-eight hours prior to accident occurrence, these were not selected for inclusion to the study because of the uncertainty of whether proficiency or fatigue would be the true factor underlying each of these variables.

Measures of airframe age and general condition were represented by the number of major overhauls or rework inductions which the accident aircraft had undergone (Aircraft Tours). Each aircraft in the Navy/Marine inventory is

required to undergo a Periodic Aircraft Rework (PAR) cycle for analysis and repair after a model specific number of flight hours have been accumulated. The number of flight hours accumulated by the accident aircraft since its last major or minor inspection was selected as a variable measure of aircraft condition. This variable was also selected as a monitor to explain any reliability anomalies other than "new-better-than-used" life expectations for critical aircraft components as mentioned by Butterworth, et al. (1974).

The Flight Purpose Code was selected as a data point because of its categorization of each flight accident in accordance with an operational mission type. Earlier studies by Kowalsky, et al. strongly suggested that training flights were a flight category rife with accident potential. Combat flights wherein the aircraft was not lost to enemy fire nor damage sustained therefrom have historically been credited with a less than average accident rate. Inclusion of basic flight purpose codes as data points was meant to clarify these prior suppositions as either correct or erroneous.

C. PRELIMINARY DATA PREPARATION

Parametric statistical procedures available for determining the relationship between variables require the assumption of normality. The data must also be in the interval measurement scale. The raw data used included some measurements in the nominal and interval measurement scales. The technique

of averaging by month was used to transform the data into interval data. In addition, transformation of the data allowed the assumption of normality by invoking the Central Limit Theorem.

Data points 2 through 9 of Table 2 were adjudged to be interval measures. Raw data for each of these variables was averaged by month for each of the seventy-two months within the total time span selected. Data point 10 was a nominal measure in its raw form and, therefore, required transformation to an appropriate list of frequencies for each of the three major flight types to be considered. The ship's hull number was used as a flag in a computer program to determine the proportion of accidents which were attributed to carrier based or land based aircraft. The Flight Purpose Code consists of a three character alphanumeric code. The second of the three characters specifies the basic mission type and was used to determine the proportion, by month, of accidents which occurred during training flights, general service flights, and combat flights. The result of the raw data transformations was the creation of eight new variables, six of which were included in subsequent parametric analysis. The new variables included in later analysis were percent carrier training flights (CVTRNG), percent carrier service flights (CVSCE), percent carrier combat flights (CVCBAT), percent land based training flights (LTRNG), percent land based service flights (LSVCE), and percent land based combat flights (LCBAT).

Variables created but not included in the analysis were percent carrier based flights and percent land based flights. Each percentage dealt only with those aircraft involved in a major accident. The new variables were adjudged to be in compliance with interval measurement scale requirements.

D. THE ANALYSIS TECHNIQUE

The stepwise multiple regression computer program package developed by Jae-On Kim and Frank J. Kohout at the University of Iowa was selected as the means of conducting the statistical analysis of the data set. The program is included in the Statistical Package for the Social Sciences (SPSS) compiled and edited by Nie, et al. (1975). Kim and Kohout state that stepwise multiple regression is a recognized technique to: 1) "find the best linear prediction equation and evaluate its prediction accuracy; 2) control for other confounding factors in order to evaluate the contributions of a specific variable or set of variables; and 3) find structural relations and provide explanations for seemingly complex multivariate relationships, such as is done in path analysis." The primary purpose, however, is to evaluate and measure overall dependence of a specific variable on a set of other variables. The specific variable (dependent variable) used for the current study was monthly accident rate and the set of other variables (independent variables) consisted of those listed as 2 through 10 in Table 2.

The computer program is designed to provide the user with a considerable number of control options. Although the majority deal with computer output formats, two of the available options can drastically affect the validity of the regression results. One such option allows the user to include all data sets in the computation of correlation coefficients. Were each data set (case) complete, the option would be harmless. However, numerous cases contained in the NSC supplied data were incomplete. The first three years or thirty-six cases lacked three critical pilot proficiency oriented data points. Variables 5, 6 and 7 of Table 2 were void of any entries for July 1968 through June 1971. Were the option invoked, the blank data points would have been evaluated as zeros and included into the computation of correlation coefficients. The resultant matrix of correlation coefficients would have been grossly biased.

More insidious but just as damaging would have been the use of an option which allowed pairwise deletion of missing data to be selected. With this option, a missing value for a particular variable causes that case to be eliminated from calculations involving that variable only. Such an option allows the user to realize maximum sample size if only a few missing values appear in his data. However, in the situation where numerous values are missing, particularly if one or a few variables account for the bulk of the missing data, the sample sizes for the individual variables would not be equal

or nearly equal resulting in serious computational inaccuracies.

Listwise deletion, a more conservative and accurate approach, provides the computer with instructions to delete any case from all computation if it contains missing variable values. The user's sample size is subject to drastic reduction in size but computations integral to the stepwise multiple regression are insured of being accurate. This option was selected for all computer runs included in the current study.

The stepwise multiple regression technique (Appendix C) is particularly useful in studies of the current type because as each independent variable is entered into the regression equation, the percentage of the total dependent variable's variance yet unexplained by the independent variables already in the regression is calculated. The percentage of the accident rate variability explained by the time related independent variables chosen is exactly the type of statistical output required to ascertain the causal factors responsible for that variability.

IV. RESULTS

Two separate regression calculations were made. The first computer run included only data points for the thirty-six month period from July 1971 to June 1974. All variables except for percent carrier based flights and percent land based aircraft were included. The second computer run encompassed the entire six year span but did not include five variables. The percent carrier and land based flights were not included nor were the three variables with excessive missing data for the period of July 1968 to June 1971. Therefore, variables 5, 6 and 7 of Table 2 were not included.

The correlation coefficients obtained for the thirty-six month run are included in Table 3. Regression results indicated that the hierarchical order of variable inclusion as governed by the individual variable contributions towards explaining accident rate variance was: 1) Pilot age; 2) Total flight time during the previous ninety days; 3) Night carrier landings during the preceding thirty days; 4) Daylight carrier landings during the preceding thirty days; 5) Total flight time in the accident involved aircraft model; 6) Total night flight time during the previous ninety days; 7) Percent carrier training flights; 8) Percent carrier service flights; and 9) Percent land based training flights. Further inclusion was inhibited by the program user through imposition of an F statistic stopping order for F values of 1.0 or less (Appendix D).

TABLE 3

MATRIX OF SIMPLE CORRELATION COEFFICIENTS

	RATE	AGE	TTIME	TOT90	NITE90
RATE	1.00000	-0.54792	0.06517	0.44988	0.23907
AGE	-0.54792	1.00000	0.17418	-0.29876	-0.14839
TTIME	0.06517	0.17418	1.00000	-0.08233	-0.47143
TOT90	0.44988	-0.29876	-0.08233	1.00000	0.40628
NITE90	0.23907	-0.14839	-0.47143	0.40628	1.00000
CLDAY	-0.15891	0.28792	-0.04861	0.20754	0.28294
CLNITE	-0.25688	0.12183	-0.05574	0.13295	0.16230
ACTOUR	-0.23495	0.34257	0.16068	-0.36285	-0.45523
ACHRS	0.34738	-0.33283	0.09483	0.40544	0.05556
CVTRNG	-0.06672	-0.05411	0.00443	-0.05277	0.33645
CVSCE	0.23746	-0.13404	-0.18301	0.08759	-0.08029
CVCBAT	0.25093	-0.19304	-0.15251	0.55128	0.28451
LTRNG	-0.03787	-0.16657	-0.04165	-0.38813	-0.29947
LSVCE	-0.26996	0.50471	0.22386	-0.13272	-0.23025
LCBAT	0.27673	-0.26953	0.12874	0.39751	0.13395

	CLDAY	CLNITE	ACTOUR	ACHRS	CVTRNG
RATE	-0.15891	-0.25688	-0.23495	0.34738	-0.06672
AGE	0.28792	0.12183	0.34257	-0.33283	-0.05411
TTIME	-0.04861	-0.05574	0.16068	0.09483	0.00443
TOT90	0.20754	0.13295	-0.36285	0.40544	-0.05277
NITE90	0.28294	0.16230	-0.45523	0.05556	0.33645
CLDAY	1.00000	0.79831	0.14288	-0.03512	-0.01193
CLNITE	0.79831	1.00000	0.00646	-0.02526	-0.02047
ACTOUR	0.14288	0.00646	1.00000	-0.27071	-0.17515
ACHRS	-0.03512	-0.02526	-0.27071	1.00000	-0.22963
CVTRNG	-0.01193	-0.02047	-0.17515	-0.22963	1.00000
CVSVCE	-0.11558	-0.19834	0.09409	0.20775	-0.14954
CVCBAT	0.16148	0.08680	-0.39118	0.64853	-0.32414
LTRNG	-0.22961	0.02469	0.21194	-0.18111	-0.33950
LSVCE	0.16272	-0.01629	0.28087	-0.35206	-0.19423
LCBAT	0.00167	0.07397	-0.22269	0.52835	-0.07665

	CVSVCE	CVCBAT	LTRNG	LSVCE	LCBAT
RATE	0.23746	0.25093	-0.03787	-0.26996	0.27673
AGE	-0.13404	-0.19304	-0.16657	0.50471	-0.26953
TTIME	-0.18301	-0.15251	-0.04165	0.22386	0.12874
TOT90	0.08759	0.55128	-0.38813	-0.13272	0.39751
NITE90	-0.08029	0.28451	-0.29947	-0.23025	0.13395
CLDAY	-0.11558	0.16148	-0.22961	0.16272	0.00167
CLNITE	-0.19834	0.08680	0.02469	-0.01629	0.07397
ACTOUR	0.09409	-0.39118	0.21194	0.28087	-0.22269
ACHRS	0.20775	0.64853	-0.18111	-0.35206	0.52835
CVTRNG	-0.14954	-0.32414	-0.33950	-0.19423	-0.07665
CVSVCE	1.00000	0.03676	-0.27935	-0.00165	-0.03445
CVCBAT	0.03676	1.00000	-0.24296	-0.37850	0.23707
LTRNG	-0.27935	-0.24296	1.00000	-0.41513	-0.07773
LSVCE	-0.00165	-0.37850	-0.41513	1.00000	-0.23649
LCBAT	-0.03445	0.23707	-0.07773	-0.23649	1.00000

The program output provided a listing of the multiple correlation coefficients (multiple R), squared coefficient values and simple correlation coefficients (simple R). Coefficient values for the predictive regression equation were also provided in both standardized and non-standardized form, BETA and B respectively. Table 4 is a summary listing of computer output provided by the SPSS package.

TABLE 4

REGRESSION OUTPUT SUMMARY
1. July 1971 to June 1974 data points

VARIABLES	MULTIPLE R	R SQUARE	SIMPLE R	REGRESSION COEFFICIENT (B)	BETA
AGE	0.54792	0.30022	-0.54792	-0.04457	-0.43384
TOT90	0.62462	0.39015	0.44988	0.00489	0.27336
CLNITE	0.67249	0.45224	-0.25688	-0.03347	-0.44456
CLDAY	0.69143	0.47807	-0.15891	0.00710	0.26089
TTIME	0.71108	0.50563	0.06517	0.00064	0.37329
NITE90	0.72415	0.52439	0.23907	0.02365	0.35557
CVTRNG	0.74319	0.55234	-0.06672	-0.00180	-0.08958
CVSVCE	0.75852	0.57535	0.23746	0.01091	0.24413
LTRNG	0.77339	0.59813	-0.03787	0.00391	0.22667
(CONSTANT)				1.10440	

An analysis of variance was conducted for the regression to determine the significance for each variable included. The null hypothesis for the tests stated that each new variable added to the regression did not significantly add to the variance for accident rate explained by variables already present in the regression. Results of computations outlined in Appendix D indicated that inclusion of TOT90 with AGE was significant at the 95% confidence level. Entry of CLNITE with AGE

and TOT90 was significant at the 90% confidence level, and inclusion of CLDAY was significant only at the 75% confidence level. Every other variable tested failed the significance tests at the 75% confidence level. In equation form the regression became:

1) RATE = 1.1044 - 0.04457 (AGE) + 0.00489 (TOT90) for a 95% confidence level.

2) RATE = 1.1044 - 0.04457 (AGE) + 0.00489 (TOT90) - 0.03347 (CLNITE) for a 90% confidence level and

3) RATE = 1.1044 - 0.04457 (AGE) + 0.00489 (TOT90) - 0.03347 (CLNITE) + 0.0071 (CLDAY) for a 75% confidence level.

Since TOT90 data points included both daylight and night flight hours, a second regression was conducted wherein corrected values for daylight hours only were used. The results were different. Order of inclusion into the computation did not change but summary output values did change. Table 5 is the summary listing of computer output for the regression using DAY90 values.

Analysis of variance testing for determination of the significance effect provided by inclusion of each variable gave the following results: 1) CLNITE with DAY90 and AGE was significant at the 90% confidence level; 2) CLDAY with CLNITE, DAY90 and AGE was significant at the 75% confidence level; 3) No other variables were significant at the 75% level or better. In equation form the regression becomes:

TABLE 5

REGRESSION OUTPUT SUMMARY
1. July 1971 to June 1974 Data Points

VARIABLE	MULTIPLE R	R SQUARE	SIMPLE R	REGRESSION COEFFICIENT (B)	BETA
AGE	0.54792	0.30022	-0.54792	-0.04457	-0.43384
DAY90	0.61296	0.37572	0.41725	0.00489	0.25258
CLNITE	0.65520	0.42928	-0.25688	-0.03347	-0.44456
CLDAY	0.68300	0.46648	-0.15891	0.00710	0.26089
TTIME	0.69602	0.48444	0.06517	0.00064	0.37329
NITE90	0.72415	0.52439	0.23907	0.02855	0.42915
CVTRNG	0.74319	0.55234	-0.06672	-0.00180	-0.08958
CVSVCE	0.75852	0.57535	0.23746	0.01091	0.24413
LTRNG	0.77339	0.59813	-0.03787	0.00391	0.22667
(CONSTANT)				1.10440	

1) RATE = 1.1044 - 0.04457 (AGE) + 0.00489 (DAY90) - 0.03347 (CLNITE) at the 90% confidence level and

2) RATE = 1.1044 - 0.04457 (AGE) + 0.00489 (DAY90) - 0.03347 (CLNITE) + 0.0071 (CLDAY) at the 75% confidence level.

The regression completed for the entire seventy-two month period of July 1968 to June 1974 wherein variables with large numbers of missing values were removed, served to support the order of inclusion for AGE and TOT90 found earlier. Because CLDAY, CLNITE, and NITE90 data points were not included in the input to the program, the regression selected LCBAT as the third variable for inclusion. No other variables were included. Analysis of variance showed TOT90 with AGE to be significant at the 95% confidence level. LCBAT inclusion was significant only at the 75% confidence level.

The residuals for this study are defined as the deviation of observed accident rate from the estimate accident rate obtained from the appropriate regression equation. The residuals are used as a basis for computation of the multiple correlation coefficients. Direct examination of the residuals also provides information relevant to the linearity and normality assumptions necessitated by the multiple linear regression technique. Regression analysis requires assumptions of error component independence, component mean of zero, and the same component variance throughout the range of dependent variable values. The SPSS package provides a visual plot of residuals against the predicted values of the dependent variable determined by the regression equation. Examination of the plot failed to reveal the presence of any abnormalities indicative of faulty assumptions for each of the computer runs made.

V. DISCUSSION

For each of the regression studies made, the pilot's age was most instrumental in explaining accident rate variance. AGE explained 30.022% of the variance for each of the thirty-six month studies. It accounted for 31.217% of the variance for the seventy-two month study. The negative simple correlation coefficients indicates that as the accident rate increased, a relatively young age group was involved. Prior studies conducted using age as a variable measure have equated age to pilot experience. The authors of this study agree that age is a measure of experience but not necessarily of pilot experience which connotes growing old at the cockpit controls. Older people tend to be more rational and prefer risk aversion to risk taking. The older a person becomes, the less impulsive he tends to be. Age also tends to provide a person with a larger repertoire of near tragedies from which to draw reminders or analogies for current situational positions.

Daylight flight time accumulated for the ninety day period preceding accident involvement, DAY90, accounted for 7.550% of the accident rate variance. Prior studies have equated this variable to a measure of pilot proficiency, as indeed it logically should be. However, the positive simple correlation coefficient associated with DAY90 would seem to refute such an interpretation. It is unlikely that the more proficient a pilot becomes, the more prone he is to accident involvement. The ninety day period is too long to attribute large numbers

of hours flown to fatigue inducement at the time of the accident. Note, however, that the actual distribution of flight hours within the ninety day period is not known and, therefore, precludes the authors from discounting the possibility of a fatigue factor with any degree of certainty. A more likely explanation would tend to follow Goorney's supposition that pilot complacency may increase directly as the number of hours flown and thus contribute to accident occurrence. No definitive explanation exists at this date for the positive correlation phenomena noted.

Both CLNITE and CLDAY simple correlation coefficients are negative and would seem to support variable categorization as measures of pilot proficiency. CLNITE accounts for 5.356% of the accident rate variance while CLDAY is responsible for 3.720%. Both variables represent the portion of a flight profile wherein pilot performance is critical. Of particular interest is the fact that the variable measure representing an almost purely instrument flight situation (CLNITE) is more critical in the explanation of accident rate variability than is the variable measure often associated with a more VFR associated flight situation. Again, risk aversion is more likely to occur under night or instrument flight conditions, whereas day or visual flight conditions seem to foster risk taking.

Regardless of whether the variable measures included in the regression are identified as belonging to pilot

proficiency or pilot experience categories, the fact that all of them were pilot oriented should impress the reader. Pilot error of one sort or another is listed as the single largest cause of aircraft accidents. Results of this study would tend to corroborate the listed cause as correct. Analysis indicates that 46.648% of the total accident rate variability is explained by pilot related variable measures, if we are willing to accept statistical confidence levels of 75% as meaningful.

VI. RECOMMENDATIONS

The current study includes all aircraft communities in its treatment of accident rates. To be so general is to miss an opportunity to isolate the true causal factors behind the accident rate fluctuations. The all Navy/Marine accident rate variability is composed of many individual components generated by different aircraft types. Each aircraft type should be analyzed separately in an attempt to ascertain commonalities between aircraft communities. Those communities which seem to contribute little or no inputs should be removed from the flight hour data necessary to compute accident rates. Aircraft types or communities which contribute heavily towards the overall accident rate would most likely not show rate fluctuations, each of which were in concert with the others. They would probably act in concert at times and at other times be diametrically opposed.

Accidents involving carrier based aircraft should be separated from those involving land based aircraft. Variable measures which deal with each community should be relegated to correlation studies with the appropriate carrier or land based accident rate. To make analytical studies relating carrier training flights with the accident rates derived from all Navy/Marine data may bury some possible correlative results which could be most informative. To demonstrate the degree in which general comparisons can result in loss of valuable information, review the regression outputs contained in Table

4 and Table 5. Removal of night flight hours from the TOT90 variable measure prompted a sizable decrease in the associated multiple correlation coefficient.

The authors of this study had as their intended goal, the analysis of accident rate by type aircraft. Flight hour data necessary to compute accident rates by aircraft type, carrier versus land communities, or by major commands was not available for use within the time constraints imposed. Follow-on studies should be encouraged to pursue a more microscopic approach to the problem in these areas. Research involving variables categorized as measures of pilot error should hold the greatest rewards if the results of this initial study are used as a guide. Fiscal policy data might also provide definitive answers, particularly in the cases where availability of funds is a key determinant in the tempo of operations. The relationship between the tempo of operations and the accident rate has been the subject of a study conducted by Robino (1972) for the Naval Safety Center. The study was somewhat broad in scope, but does tend to encourage a more detailed study into this area.

APPENDIX A

AVERAGE MONTHLY DATA POINT VALUES

FISCAL YEARS

	1969	1970	1971	1972	1973	1974	AVG
JUL	1.26	1.64	1.65	.49	1.32	1.00	1.22
AUG	1.35	1.52	1.31	.96	.96	.77	1.14
SEP	1.16	1.18	1.22	.85	.75	.87	1.01
OCT	1.51	1.15	1.03	.89	.63	.97	1.03
NOV	1.36	1.23	1.52	.76	1.13	.94	1.15
DEC	1.20	1.12	.89	1.15	1.10	.82	1.05
JAN	1.83	.94	.82	1.09	.98	.77	1.07
FEB	1.58	1.59	1.61	.72	.61	.60	1.12
MAR	1.59	1.82	.91	.73	.91	.69	1.11
APR	1.27	.91	.93	1.17	.89	.44	.94
MAY	1.53	1.42	.58	.78	.90	.68	.98
JUN	1.30	1.90	1.16	1.34	.74	.44	1.15

ALL NAVY/MARINE MAJOR ACCIDENT RATES

1. RATE = (# ACCIDENTS PER MONTH) 10,000/TOTAL FLIGHT HOURS PER MONTH

TABLE A1

YR/MO	AGE	TTIME	TOT90	NITE90	CLDAY	CLNITE	ACTOUR	ACHRS
6807	29.92	359.39	87.56				3.86	102.39
08	27.64	413.37	83.98				4.52	101.88
09	30.29	390.15	75.78				3.64	70.20
10	29.11	395.66	91.83				3.92	88.00
11	29.38	371.82	83.52	4.00			3.50	139.43
12	29.66	403.59	93.23				3.42	101.00
6901	29.08	410.63	73.92				3.00	95.57
02	29.16	463.30	74.89				4.07	95.13
03	28.74	360.75	66.63				4.64	68.15
04	28.07	346.43	67.62				3.62	88.62
05	28.89	384.91	88.98				4.08	87.91
06	28.81	350.60	97.74				5.00	79.30
07	28.79	417.75	93.65				3.83	75.41
08	30.20	472.28	81.85				3.80	83.49
09	28.97	410.61	89.09				3.88	107.00
10	29.77	473.45	80.32				3.96	68.30
11	29.13	371.09	73.23				2.71	92.48
12	29.72	372.71	66.04				3.27	80.56
7001	30.50	466.84	72.11				4.00	115.56
02	29.00	451.35	78.57				3.13	105.03
03	29.27	534.48	89.90				3.47	85.84
04	29.60	383.60	77.71				3.53	92.78
05	30.55	528.47	79.87				4.10	93.00
06	28.48	393.37	75.29				3.51	89.03
07	29.64	406.10	68.78				4.11	82.30
08	29.62	466.55	76.90				4.28	116.26
09	28.74	474.84	69.35				3.48	81.38
10	29.75	457.83	99.13				2.47	69.00
11	27.42	340.91	83.59				4.13	128.22
12	31.28	429.17	65.28				4.00	143.36
7101	30.47	512.94	70.59				4.08	62.58
02	30.38	450.54	74.86				3.57	95.00
03	28.58	336.46	69.79				3.56	56.18
04	28.54	413.54	78.26				3.47	111.94
05	28.57	351.07	76.07				5.10	113.67
06	29.45	478.61	69.47	4.67			3.87	110.00

AVERAGE MONTHLY DATA POINT VALUES
1. July 1968 through June 1971.

TABLE A2

YR/MO	AGE	TTIME	TOT90	NITE90	CLDAY	CLNITE	ACTOUR	ACHRS
07	30.45	422.91	61.18	16.90	10.20	5.00	3.71	94.00
08	30.13	417.00	72.39	12.81	9.75	3.83	3.84	117.15
09	28.53	565.05	82.16	11.12	6.00	5.00	3.44	97.47
10	31.10	584.80	75.30	9.50	11.14	4.20	3.28	151.61
11	31.00	568.94	65.71	11.27	8.00	4.33	2.76	130.19
12	29.61	807.39	96.30	14.35	9.80	4.00	3.82	106.89
7201	28.00	459.82	68.27	17.53	10.56	3.20	2.76	111.67
02	31.14	571.86	76.64	15.54	12.00	3.25	3.23	122.69
03	32.25	429.65	58.71	17.13	11.14	4.00	3.31	113.24
04	29.85	538.59	71.52	13.31	9.13	5.80	3.35	98.56
05	31.00	537.84	84.53	12.72	18.29	4.00	2.68	116.61
06	29.17	508.83	82.09	14.62	19.50	6.20	3.32	134.55
07	28.82	511.96	79.54	12.56	8.56	4.14	4.11	123.27
08	27.91	459.96	79.52	12.05	9.25	3.43	4.36	97.68
09	31.06	520.24	93.53	12.60	20.11	7.50	3.22	125.06
10	30.50	572.43	78.29	11.83	11.33	6.33	3.33	129.43
11	30.13	562.96	71.22	14.33	9.82	5.00	2.77	148.14
12	29.33	487.89	69.74	14.44	14.29	3.33	4.00	76.95
7301	31.62	657.07	84.67	15.45	14.66	4.17	3.75	164.95
02	32.08	570.08	51.17	8.40	11.00	2.00	4.42	82.27
03	31.90	659.60	66.90	10.76	7.00	2.00	3.05	102.44
04	30.00	540.68	63.16	10.56	5.50	2.67	4.26	78.05
05	32.55	658.25	66.50	13.83	9.00	4.88	3.70	74.70
06	32.07	677.38	68.54	10.08	10.00	2.75	3.23	73.85
07	30.80	729.26	75.17	7.71	12.00	2.67	4.29	81.17
08	31.73	682.93	66.57	8.46	7.50	3.00	4.71	76.29
09	29.47	762.27	73.27	13.69	9.29	4.17	3.47	92.33
10	28.50	429.20	64.00	17.80	17.67	3.00	4.19	62.06
11	33.13	696.69	61.88	10.07	7.33	1.00	3.67	36.20
12	35.10	164.60	99.60	21.50	16.67	3.00	3.38	53.50
7401	37.00	778.89	50.56	12.13	8.00	0.00	4.44	75.90
02	33.89	484.89	50.22	5.29	0.00	0.00	5.63	84.11
03	29.27	347.08	55.58	12.45	9.33	6.00	3.22	42.67
04	36.50	633.00	64.13	12.75	52.50	18.00	5.29	60.71
05	32.00	503.73	66.93	15.57	9.83	7.50	2.38	25.25
06	33.00	579.25	51.25	7.33	6.00	6.00	4.50	72.14

AVERAGE MONTHLY DATA POINT VALUES
1. July 1971 through June 1974.

TABLE A3

YR/MO	CVPCT	CVTRNG	CVSVCE	CVCBAT	LPCT	LTRNG	LSVCE	LCBAT
6807	35.00	10.00	2.50	22.50	65.00	35.00	17.50	12.50
08	48.94	12.77	8.51	27.66	51.06	27.66	12.77	10.64
09	36.36	12.12	3.03	21.21	63.64	33.33	24.24	6.06
10	24.53	9.43	5.66	9.43	75.47	37.74	22.64	15.09
11	33.33	14.29	9.52	9.52	66.67	40.48	11.90	14.29
12	33.33	30.30	3.03	0.00	66.67	42.42	12.12	12.12
6901	44.62	38.46	3.08	3.08	55.38	33.85	15.38	6.15
02	37.78	22.22	4.44	11.11	62.22	40.00	20.00	2.22
03	29.63	14.81	3.70	11.11	70.37	38.89	27.78	3.70
04	29.27	14.63	2.44	12.20	70.73	51.22	14.63	4.88
05	26.42	11.32	1.89	13.21	73.58	33.96	22.64	16.98
06	34.88	23.26	9.30	2.33	65.12	37.21	25.58	2.33
07	35.42	12.50	8.33	14.58	64.58	41.67	14.58	8.33
08	38.30	14.89	6.38	17.02	61.70	40.43	17.02	4.26
09	47.22	27.78	8.33	11.11	52.78	22.22	19.44	11.11
10	46.88	25.00	9.38	12.50	53.13	34.38	15.63	3.13
11	31.25	15.63	0.00	15.63	68.75	50.00	12.50	6.25
12	26.92	3.85	7.69	15.38	73.08	53.85	3.85	15.38
7001	50.00	45.00	0.00	5.00	50.00	30.00	20.00	0.00
02	40.00	20.00	5.00	15.00	60.00	30.00	22.50	7.50
03	44.90	28.57	6.12	10.20	55.10	28.57	22.45	4.08
04	51.85	18.52	14.81	18.52	48.15	25.93	22.22	0.00
05	53.85	10.26	10.26	33.33	46.15	25.64	17.95	2.56
06	30.77	11.54	7.69	11.54	69.23	53.85	11.54	3.85
07	28.89	11.11	4.44	13.33	71.11	55.56	11.11	4.44
08	36.67	23.33	3.33	10.00	63.33	30.00	30.00	3.33
09	37.50	28.13	6.25	3.13	62.50	56.25	6.25	0.00
10	48.00	28.00	4.00	16.00	52.00	20.00	20.00	12.00
11	25.71	17.14	5.71	2.86	74.29	60.00	11.43	2.86
12	36.84	10.53	10.53	15.79	63.16	36.84	26.32	0.00
7101	35.29	17.65	0.00	17.65	64.71	35.29	17.65	11.76
02	41.67	19.44	2.78	19.44	58.33	44.44	13.89	0.00
03	36.00	24.00	4.00	8.00	64.00	44.00	16.00	4.00
04	20.83	16.67	4.17	0.00	79.17	62.50	12.50	4.17
05	35.71	28.57	7.14	0.00	64.29	42.86	21.43	0.00
06	37.93	17.24	6.90	13.79	62.07	37.93	24.14	0.00

AVERAGE MONTHLY DATA POINT VALUES
1. July 1968 through June 1971.

TABLE A4

YR/MO	CVPCT	CVTRNG	CVSVCE	CVCBAT	LPCT	LTRNG	LSVCE	LCBAT
07	50.00	41.67	8.33	0.00	50.00	25.00	25.00	0.00
08	25.00	8.33	4.17	12.50	75.00	62.50	12.50	0.00
09	15.79	5.26	0.00	10.53	84.21	63.16	15.79	5.26
10	33.33	19.05	9.52	4.76	66.67	47.62	14.29	4.76
11	33.33	11.11	5.56	16.67	66.67	44.44	22.22	0.00
12	26.09	17.39	0.00	8.70	73.91	39.13	30.43	4.35
7201	34.78	8.70	13.04	13.04	65.22	43.48	21.74	0.00
02	35.71	28.57	0.00	7.14	64.29	42.86	14.29	7.14
03	37.50	18.75	0.00	18.75	62.50	56.25	6.25	0.00
04	32.14	21.43	3.57	7.14	67.86	60.71	3.57	3.57
05	50.00	10.00	5.00	35.00	50.00	50.00	0.00	0.00
06	50.00	20.83	16.67	12.50	50.00	29.17	16.67	4.17
07	27.59	10.34	3.45	13.79	72.41	55.17	17.24	0.00
08	37.50	20.83	12.50	4.17	62.50	58.33	4.17	0.00
09	57.89	21.05	0.00	36.84	42.11	21.05	21.05	0.00
10	26.67	20.00	0.00	6.67	73.33	46.67	20.00	6.67
11	47.83	30.43	0.00	17.39	52.17	43.48	4.35	4.35
12	40.00	20.00	10.00	10.00	60.00	40.00	15.00	5.00
7301	52.63	5.26	10.53	36.84	47.37	31.58	10.53	5.26
02	8.33	8.33	0.00	0.00	91.67	41.67	50.00	0.00
03	25.00	15.00	10.00	0.00	75.00	35.00	40.00	0.00
04	44.44	33.33	5.56	5.56	55.56	44.44	11.11	0.00
05	30.00	25.00	5.00	0.00	70.00	60.00	10.00	0.00
06	50.00	42.86	7.14	0.00	50.00	28.57	21.43	0.00
07	28.57	19.05	9.52	0.00	71.43	33.33	38.10	0.00
08	18.75	12.50	6.25	0.00	81.25	56.25	25.00	0.00
09	43.75	43.75	0.00	0.00	56.25	50.00	6.25	0.00
10	40.00	40.00	0.00	0.00	60.00	50.00	10.00	0.00
11	12.50	12.50	0.00	0.00	87.50	50.00	37.50	0.00
12	45.45	27.27	9.09	9.09	54.55	18.18	36.36	0.00
7401	30.00	30.00	0.00	0.00	70.00	40.00	30.00	0.00
02	10.00	0.00	10.00	0.00	90.00	70.00	20.00	0.00
03	23.08	23.08	0.00	0.00	76.92	69.23	7.69	0.00
04	12.50	12.50	0.00	0.00	87.50	50.00	37.50	0.00
05	23.53	23.53	0.00	0.00	76.47	52.94	23.53	0.00
06	33.33	22.22	11.11	0.00	66.67	44.44	22.22	0.00

AVERAGE MONTHLY DATA POINT VALUES
1. July 1971 through June 1974.

TABLE A5

APPENDIX B

AIRCRAFT ACCIDENTS BY MONTH AND TYPE AIRCRAFT

ACFT	6807	6808	6809	6810	6811	6812	6901	6902	6903	6904	6905	6906
A-1		1		2				1				1
A-3	1	1	1	4	1	2	5	2	1			
A-4	10	14	6	6	6	9	10	14	7	7	10	9
A-5	2		2		2		3	1	2			2
A-6	1	3		1		1	19	1	3	2		1
A-7	1	2	4	4	1	3			4	10	6	5
C-1		1			1	1			1			
C-45			1							1		
C-47										1	1	
C-54												1
C-117							1				1	
C-130	1				1						1	
E-1	1	2						1	1	1		
E-2			1	1			3					
F-4	2	6	3	4	6	2	23	14	7	2	7	
F-8	8	7	4	5	6	2	8	7	8	9	6	4
F-9	2	3	2	4	3	3		1	4	1	3	6
F-10				1					1			
F-111			1									
H-1	2	3	3	4	4	2	4	2	2	2	8	2
H-2	1			1	1	1	2	1	1		1	1
H-3	1		2			2		1	1			1
H-19							1		1			
H-34			2	2	4	1	3	2		2	1	2
H-46	2	3	1	4	2	2	4	1	3	2	4	4
H-53	1					1			2	1	2	
O-1	2	1		2								
OV-10	1										2	
P-2								1	2		2	
P-3								1	1			1
S-2		1	1	1	1		1	2		1	1	
T-1		1					1					
T-2	2			4	3	1	1	2	2	1		2
T-28	1			2		1	1		1	1	1	1
T-33									1	1		
T-34			1	2								
U-16											1	

ACCIDENT OCCURRENCE BY MONTH AND TYPE AIRCRAFT
1. July 1968 through June 1969

TABLE B1

ACFT	6907	6908	6909	6910	6911	6912	7001	7002	7003	7004	7005	7006
A-1			1									
A-3	1	2	1				1	2			1	
A-4	15	12	4	8	7	4	4	7	4	5	6	10
A-5			1	1		1	2	2	1		1	
A-6	1	2	2		1	2	1	2	1	2		3
A-7	5	3	2	2	6	2	1	4	7	6	5	11
C-1	1			1							1	
C-2				1								
C-45							1		1			
C-47	1	1										
C-54	1											
C-117						1						
C-121									1			
CUB									1			
E-1		1	1	1							1	2
E-2										1		
F-4	4	4	5	7	4	9	2	6	9	2	5	8
F-8	5	8	2	2	2	9	3	5	9	4	5	5
F-9		2	4	1	2	1			3		2	2
F-111				1								
H-1	4	1	3	2	2	3	2	3	3	2	3	4
H-2		3	1				1					
H-3	1		3			1	1	3			1	
H-34	1	1			1	1		2	3	3	2	1
H-37								1				
H-46	2	4	1	1	1	1	1	3	6	2	2	
H-53	1		1		1			1			1	
H-57								1			1	1
O-1			1									
OV-10	1	2			2							
P-2		1	1							1		
S-2	2			2	2				1	1		
T-1	1				1							
T-2	1	1	1				1	1		1	1	2
T-28	2		1	2	1			1	1			2
T-29								1				
T-33	1					1					1	2
T-34				1					1			
T-39										1		

ACCIDENT OCCURRENCE BY MONTH AND TYPE AIRCRAFT
1. July 1969 through June 1970

TABLE B2

ACFT	7007	7008	7009	7010	7011	7012	7101	7102	7103	7104	7105	7106
A-3	1	3		1		1		1			1	4
A-4	9	1	6	1	2	2	1	7	7	5	4	7
A-5	1	1	1							1		
A-6		1	3		1		3	3	4	1		
A-7	4	4	2	4	4	5	1	3	4	3	2	7
AV-8												1
C-1						1			1	1		
C-2						1						
C-45	1				1							
C-117						1						
C-118										1		
C-119								1				
C-121				1								
C-130	1	1						1				
C-131					1							
DC-9												1
E-1	1				1			2				
E-2						1			1	1		
F-4	7	6	4	5	6		3	6	3	1	4	6
F-8	2	5	8	4	2	1	2	3	4	2	1	2
F-9	1		4		3	1					1	
H-1	4	2		5	4	1	2	1	1	1		2
H-2				1								
H-3			1	1	2	1		2		1		2
H-46	2	2			1	1	1	1		2		
H-53	1			1			1	2		2		
H-57					1							
H-58								2				
OV-10	1	1			1	1	1		1		2	
P-3		1										
S-2	1	1		1	1		2	3				
T-1	1				2							
T-2	1	1	3		2			2	1			
T-28	3				1	1	1	1		2		
T-34	1											
U-11										1		
X-26									1			

ACCIDENT OCCURRENCE BY MONTH AND TYPE AIRCRAFT
1. July 1970 through June 1971

TABLE B3

ACFT	7107	7108	7109	7110	7111	7112	7201	7202	7203	7204	7205	7206
A-3		1					1			1		1
A-4		8	3	2	6	2	1	3	2	6	4	1
A-5				1			1		2	1		
A-6	1	1		3	1		1			3	2	1
A-7	1	1	5	4	3	3	5	4	6	2	4	6
C-1							1					
C-2		1				1	1					
C-130						3	1					
E-1	1											
E-2	1			1								
F-4	2	3	2	2	2	2	3	1	4	6	4	5
F-8		1	1	1		2	3	2	1	3		
F-9				1						2		
F-14												1
F-104							1					
H-1	3	2	4	2	1	1		1		1	1	3
H-2				1							1	2
H-3	1		1			1	1				1	1
H-34		1		1	1							
H-46		1	1		1	4				2		
H-53	1						1	1	1			
O-1										1		
OV-10							1	1			1	
P-3						2					1	1
S-2			1		2			1	2			
T-2			1	1	1	2	1			1		
T-28	1	1		1		1		1				1
T-33		1										1
T-34		1										
T-39		1										
U-16			1									
X-26											1	

ACCIDENT OCCURRENCE BY MONTH AND TYPE AIRCRAFT
1. July 1971 through June 1972

TABLE B 4

ACFT	7207	7208	7209	7210	7211	7212	7301	7302	7303	7304	7305	7306
A-3			1	2			2	1				
A-4	6	5	4	3	7	2	1	5	6	2	4	3
A-5										1		
A-6	3	2	1	2	2	2			1		3	
A-7	4	1	3	5	4	1	4	2		3	4	1
AV-8									1			
C-1						1	1					
C-2							1				1	
C-117						1						
C-118									1			
C-130							1					
CONVAIR 990										1		
E-1	2											1
E-2		1				1						1
F-4	7	5	2	5	3	5	7	2	5	5	4	1
F-8	1	3	4		1	2			1	2	3	2
F-9	2	1				1						
F-14												1
H-1			2		1		1					
H-2		1	1				1		1	1		1
H-3	1			1		1	5					1
H-46		1		1		2		1	1			
H-53	1			1	1	1	1	1	4	1		
H-57		2										
OV-10												1
P-2		1								1		
P-3									1	1		
S-2					1			1		1		
T-2	1	1										1
T-28	1		1		3						2	
T-33							1					
T-34				2		1						
T-38					1							
T-39				1								
U-11										1		
U-16												1

ACCIDENT OCCURRENCE BY MONTH AND TYPE AIRCRAFT
1. July 1972 through June 1973

TABLE B5

ACFT	7307	7308	7309	7310	7311	7312	7401	7402	7403	7404	7405	7406
A-3	1	2	1						1			
A-4	1		4	4	1		2	3	4	3	4	1
A-5	1		1						1			
A-6	1		1	1	2				1		1	
A-7	2	1	2	2	1	2	2		3		5	1
AV-8												1
C-2	1				1							
C-117					2		1	1				
C-118						2						
C-130							1					
E-1	1											
E-2										2		
F-4	4	3	2	5	5	1	1	1	1	1	2	3
F-8	5	4	3	5	1		1					
F-9				1			1					
F-14											1	
H-1	1			1	1	3	1	1		1	1	
H-2		1										
H-3				1	1			1	1	1		
H-46		2			1	1				4		3
H-53	2	1								2	1	
OV-10						1						
P-2	1		1									
S-2	1					1	1					
S-3		1			1							
T-2											2	
T-28		1	1					1				1
T-33									1			
T-34								2				
TC-4				1								

ACCIDENT OCCURRENCE BY MONTH AND TYPE AIRCRAFT
1. July 1973 through June 1974

TABLE B6

APPENDIX C

STEPWISE MULTIPLE REGRESSION

Basic multiple regression is an analytical technique whereby a linear approximating equation is sought for a dependent variable in terms of two or more independent variables. The general mathematical model for multiple regression in its unstandardized form is

$$Y' = A + b_1X_1 + b_2X_2 + \ldots + b_kX_k$$

where Y' is the regression estimate value of the dependent variable, A is the Y intercept constant, b_i represents the regression coefficients, and X_i are the independent variables.

The objective sought in the conduct of multiple regression is to find the best linear predictive equation possible by insuring that the sum of squared residuals, $\Sigma\ (Y - Y')^2$, is minimized. By minimizing the sum of squared residuals, the regression technique purports to maximize the correlation between Y, the observed dependent variable value, and Y', the regression estimate.

The goodness of fit of the regression equation can be characterized by the proportion of variance explained for Y. To do so, the square of the multiple correlation, R^2, is used. R^2 is calculated by:

$$R^2 = \frac{SS_y - SS_{res}}{SS_y} = \frac{SS_{reg}}{SS_y} = \frac{\Sigma\ (Y' - \bar{Y})^2}{\Sigma\ (Y' - \bar{Y})^2 - \Sigma\ (Y - Y')^2}$$

where SS_Y is the total variation or sum of squares in Y, SS_{res} is the sum of squared residuals, and SS_{reg} is the regression of squares. The numerator for the right hand portion of the equation represents the variation in Y explained by the combined linear influence of the independent variables. The denominator is a measure of the total variation in Y.

The determination of the regression equation stems from the simultaneous solution of the standardized normal equations

$$\begin{array}{lcl}
B_1 + B_2r_{12} + B_3r_{13} & + \dots + B_kr_{1k} & = r_{Y1} \\
B_1r_{12} + B_2 + B_3r_{23} & + \dots + B_kr_{2k} & = r_{Y2} \\
 & \vdots & \\
B_1r_{1k} + B_2r_{2k} + B_3r_{3k} & + \dots + B_k & = r_{Yk}
\end{array}$$

where B_i are the standardized regression coefficients of the independent variable X_i, and r_{ij} are the Pearson or product moment correlations between variable X_i and X_j.

Stepwise inclusion of independent variables available in the Statistical Package for the Social Sciences (SPSS version 6) used for this study allows entry of each variable, one at a time. Inclusion criteria are such that the order of variable entry is dictated by accountability of each for previously unexplained variance. Thus, the variable that explains the greatest amount of variance previously unexplained by the variables already in the equation is the next to be entered.

APPENDIX D

STATISTICAL TESTS FOR SIGNIFICANCE

Procedural statistical testing for goodness of fit for the regression equation is accomplished by conducting Analysis of Variance (ANOVA). The null hypothesis, H_O, used for the testing is that the next variable to be added in a stepwise manner would not add significantly to the explained variance in the dependent variable, Y, already accounted for by variables included in the regression equation. The alternative hypothesis, H_1, directly contradicts the null hypothesis. An equivalent statement of H_O would be that all "k" of the regression coefficients would be identically equal to zero as opposed to the H_1 statement of at least one coefficient not equating to zero.

The first step of stepwise regression with forward elimination is for each of the independent variables to be individually regressed against the dependent variable. F statistics are computed for each dependent-independent variable pair. The pair having the highest F statistic computed is permanently selected for inclusion into the regression equation. The F statistic used in the first step is

$$F = \frac{r^2_{Y1}/\,1}{\left[1-R^2_{Y.1,2,\ldots,k}\right]/\,(N-k-1)}$$

where r_{Y1} is the simple correlation, $R_{Y.1,2,...,k}$ is the multiple correlation for "k" independent variable inclusion, and "k" is the number of independent variables entered. N is the sample size used in the particular regression under consideration.

For each successive step in determining the regression equation, variables in the equation are retained and independent variables not in the equation are temporarily entered for F statistic computation. At each step, the combination of variables resulting in the highest F statistic is kept. The general form of the F statistic used for each successive step is

$$F = \frac{(\text{incremental SS due to } X_k)}{SS_{res} \;/\; (N-k-1)} = \frac{r^2_{Y(k.1,2,...,k-1)}/1}{(1-R^2_{Y.1,2,...,k})/(N-k-1)}$$

where SS is the sum of the squares, X_k is the k^{th} independent variable to be added, SS_{res} is the sum of squares of the residuals, and $r_{Y(k.1,2,...,k-1)}$ is the partial correlation between Y and X_k when X_i, $i = 1,2,...,k-1$ are held fixed.

After all independent variables which contribute to the explained variance have been added to the regression equation in the order dictated by the amount of variance accounted for, the significance of each added variable can be determined through use of a separate F statistic. The general form for the statistic is

$$F = \frac{[R^2_{Y.(1,2,...,k)} - R^2_{Y.(1,2,...,k-1)}]/\ M}{[1-R^2_{Y.(1,2,...,k)}]/\ (N-k-1)}$$

where "k" is the number of the variable to be tested for inclusion and M is the degree of freedom commensurate with the variable(s) tested.

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